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Transfer, adaptation and diffusion of mature renewable energy technologies in developing countries

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PREFACE

This report has been prepared pursuant to Conference resolution 143 (VI) of July 1983, and resolution 326 (XXXI) of the Trade and Development Board of 27 September 1985, in which the Secretary-General of UNCTAD was requested, inter alia, to convene a meeting of an intergovernmental group of experts on the transfer, application and development of technology in the energy sector, paying particular attention to new and renewable sources of energy. The terms of reference of this meeting, as defined in paragraph 1 of the above-mentioned Board resolution, are as follows:

(i) To consider documentation related to this subject submitted to it by the UNCTAD secretariat and views and comments thereon by Governments and relevant United Nations bodies;

(ii) To examine in detail practical issues of relevance to developing countries relating to the transfer, application and development of technology in particular in the field of new and renewable sources of energy and taking into account the problems of assimilation and adaption of these technologies to local conditions on the basis of up-to-date experience;

(iii) To draw general conclusions from the discussions and to recommend appropriate policies including concrete measures in this sector to be considered at the sixth session of the Committee on Transfer of Technology; and,

(iv) To report to the Committee on Transfer of Technology at its sixth session.

SUMMARY AND CONCLUSIONS

(i) Widespread utilisation of mature renewable energy technologies,*/ particularly in developing countries, has been an underlying theme of many international discussions and programmes of bilateral and multi-lateral co-operation on renewable energy during the last several years, as reflected in the Programme of Action adopted at the United Nations Conference on New and Renewable Sources of Energy (Nairobi, August 1981). After having carried out numerous projects for the evaluation, testing and demonstration of different mature technologies, Governments, particularly of developing countries, now seem to be paying increasing attention to application and diffusion of these technologies, especially in rural areas.

(ii) The present paper reviews some of the issues relating to the transfer, adaptation and diffusion of mature, renewable energy technologies, with a particular focus on the role of domestic equipment manufacture in this process. Particular attention has been paid to those technologies (such as solar water-heaters, windmills, small hydro-turbines, etc.) that can be made through simple metal-working processes even in those countries where industrial and technical capabilities are relatively limited. In contrast to diffusion based on equipment import, reliance on domestic equipment manufacture as a mechanism for technology diffusion can have a number of advantages such as possible foreign exchange saving, appropriateness of the resultant technology and availability of repair facilities, given the proximity of producers to users, employment creation and skill generation. The resulting stimulation to the manufacturing industry may, in turn, have important consequences for both industrial and agricultural development. This does not mean, however, that domestic equipment manufacture should be preferred in all cases; the case for reliance on that approach has to be examined carefully on a case-by-case basis. The present paper represents an exploratory attempt to sort out some conceptual issues on the basis of the available empirical examples.

(iii) The diffusion of a technology requires that demand for it exist or can be generated. This implies that the financial benefits of purchasing the equipment must be sufficient to overcome any risks of loss of income through non-performance of the technology and must also overcome any social constraints and inhibitions. The availability of credit at reasonable rates and moderate collateral is therefore extremely important. In addition to the demand which may arise in a spontaneous manner out of the 'private' calculations of benefits and costs by individual users, the Government may adopt a policy to stimulate such demand for given economic or social ends. For example, in countries where use of kerosene is subsidized in a way that cannot be altered, the Government concerned may provide a capital subsidy for purchase of renewable energy equipment.

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*/ Mature technologies are defined as those technologies that are technically and economically feasible and are readily available on the market in many locations with reasonable assurance of working according to specifications.

(iv) Many different types of actors are usually involved in the diffusion process; in addition to consumers, they include producers, distributors of the technology, financing agencies, and operators of repair and maintenance facilities. For the creation of a stable market, which is a necessary condition for wide-spread diffusion of technology, it is essential that all of these actors become involved. This implies that the benefits to each group of involvement in the new market must be at least as great as other options open to them. Domestic manufacture of renewable energy equipment can take place in rural workshops or in larger and more modern factories. Rural workshops may be better able to serve rural communities due to their geographical proximity to a large number of potential users of mature renewable energy technologies. However, products from these workshops are often not of a satisfactory quality to guarantee reliable equipment operation. Additionally, interventions by the Government are more difficult and, as a result, usually restricted to more indirect activities. Attempts are, however, being made in some developing countries to link the activities of domestic R and D institutes to the operation of these workshops so that the latter may have access not only to improved designs, but also to testing facilities. This would strengthen considerably the effectiveness of their role in diffusion.

(v) Factory production in urban or semi-urban locations may be more advantageous for organized equipment manufacture. The initiation of such activity, however, is far from easy on account of various constraining factors, including large risks that have to be borne by the entrepreneur because of market uncertainties. Limited access to technical information may also pose a problem for the entrepreneur. For the type of mature technologies discussed in the paper, foreign technology may not be appropriate; and, even if appropriate technology exists, the information cost may be high. The contribution of domestic R and D institutes in this area also seems to be limited, owing to absence of effective linkages. Inadequate functioning of distribution channels for the equipment produced could be another source of problems.

(vi) The Government can play an important role in promoting the diffusion of mature renewable energy technologies and has at its disposal a number of policy instruments. It can be responsible for providing information on such technologies to both consumers and manufacturers. It can provide credit services to consumers, and through taxes and subsidies influence the economics of the renewable energy technology and its alternatives. It can also be more actively involved, either through direct purchases of certain quantities of the equipment from domestic manufacturers or by the investment of equity in the producing factory. The role that the Government should assume in a particular country would obviously depend on a variety of factors, including its development policy, energy setting, policy approach to renewable energy technology and endowment of human and financial resources that may be mobilized for diffusion of mature renewable energy technology.

(vii) International co-operation through bilateral and multilateral channels can play an important role in supporting the national efforts of developing countries for mature renewable energy technology diffusion. Developing countries may also combine their national efforts in order to benefit from complementarity. Areas for such co-operation may include promotion of network arrangements to stimulate international dissemination of information,

particularly on performance and costs of the installed technologies and regional unpackaging of mature renewable energy technology projects to identify complimentarity in equipment or component supply and to assess feasibility of joint equipment manufacture. Official development co-operation from developed countries in the area of renewable energy may be directed to the strengthening of domestic diffusion mechanisms in developing countries. Instead of equipment donation, such co-operation can, for example, be made to support workshops and plants in developing countries which are capable, with additional technical and financial means, of reproducing mature technology for diffusion. Finally, it will be useful to organize an exchange of diffusion experience among developing countries, especially in respect to the policy employed to stimulate technology diffusion.

Chapter I

INTRODUCTION

1. While major innovations and scientific and technical advances have played a crucial role in long-term economic growth, more modest changes of technology can also be important, if not necessary, for economic development. In a dynamic economy, the best methods of performing specific tasks change, and it is quite possible that the most suitable method, although well understood, is not widely used. This paper discusses the barriers to the diffusion of some renewable energy technologies which might conceivably belong to this category. The discussion is focused on mature technologies for which there are no significant remaining technical hurdles to overcome, and that can be produced with relatively simple mechanical engineering process (e.g. welding, casting, sheet bending etc.), the examples being solar water heaters, windmills, small hydro-turbines, and solar driers amongst others.

2. Widespread utilization of mature renewable energy technologies, particularly in developing countries, has been an underlying theme of many international discussions held on renewable energy during the last several years. The spreading of these technologies has been expected not only to open up the prospect of increasing indigenous energy supply, and thereby contribute to greater self-sufficiency, but also to set in motion a dynamic process of development, particularly in areas where the use of more conventional energy has been limited. The programme of action adopted at the United Nations Conference on New and Renewable Sources of Energy (Nairobi, 10 - 21 August 1981) reflected this concern explicity and included transfer, adaptation and application of such technologies as an area for priority action.[1/] As called for in this programme, numerous projects of international co-operation have been carried out through both bilateral and multilateral channels to support national efforts of developing countries in this area.[2/] These projects were in large part for evaluation, testing and demonstration of different technologies in different socio-economic and energy settings and for training of technical personnel in developing countries.[3/]

3. The results of the international co-operation projects appear to be mixed, which perhaps should have been expected to some extent in view of the pilot character of many of them. If anything, the principal finding is that the appropriate choice of technology in a particular setting depends on a wide variety of factors which differ from one country to another, and within one country from one location to another.[4/] At the same time, however, there is a realisation that a wide gap remains between the experimental or pilot work and the application stage in the development of renewable energy technologies in developing countries. Based on such recognition, experts convened by ESCAP concluded that the thrust of their regional co-operation programme should be placed on the "improvement, adaptation, application, standardization and commercialization of mature renewable energy technologies

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1/ See United Nations (1981), pp. 26 - 27.

2/ For an over-view of reported co-operation activities, see United Nations, (1986), chapter III.

3/ Commission of the European Communities (1983), FAO (1985) and United Nations (1985).

4/ See G. Oelert et al. (1985) for a recent economic assessment study.

as well as their demonstration and manufacture of related equipment".[5] A similar shift in emphasis is also observed in the work of some United Nations organizations engaged in rural development.[6] There is a corresponding movement in the discussion of industrial development to focus on the possibility of manufacturing energy capital goods, including renewable energy equipment, in developing countries.[7]

4. It is important to recognize, however, that the issues relating to mature technology diffusion are not unique to renewable energy technologies. The diffusion of windmills or small hydro-turbines is in many respects similar to the diffusion of diesel engines, as is that of solar water-heaters to kerosene heaters, and of solar driers to other farm implements. Naturally the focus on constraints may change in emphasis depending on the technology but similar issues will nonetheless be addressed. From the policy-makers' point of view one such issue of great importance concerns the role of domestic equipment manufacture, as contrasted to that of equipment imports, in technology diffusion.

5. There are arguments both for and against using imports (or domestic equipment manufacture) as a means of equipment supply for widespread diffusion of mature technology in developing countries. The arguments for relying on imports include immediate availability and reliability of the technology (the latter in the sense that it has been well tested). It may be the cheapest way, especially if the international industry is competitive and the local industry weak. To the extent that the equipment supply takes place as aid, it may also be the only way in a given circumstance. There are, however, problems associated with this means. They include foreign exchange burden, possible inappropriateness of the technology (or put another way, the desired technology may not exist), and the large information cost because of the diffused character of suppliers (this would particularly be the case for suppliers from other developing countries). Last, but not least, repair and maintenance, and supply of spare parts may pose a problem for efficient use of the technology.

6. Diffusion of mature technology through local equipment manufacture can solve some of the problems mentioned above, such as inappropriateness through adaptation of design and raw materials to local conditions, foreign exchange burden through partial or total import-substitution, repair and maintenance problems with the closeness of suppliers to users. There are also other advantages such as local resource utilisation, employment creation, skill generation and other dynamic impacts on economic development. This means, of course, is not without problems and disadvantages. They include roundaboutness in procurement if immediate local supply capability does not exist, possible high production cost for a variety of reasons such as small size of market, lack of technical knowledge and skills, absence of component suppliers, etc. Lastly, and this is fundamental, equipment manufacture requires a broad base as far as the demand is concerned, so that as a point of departure for policy consideration either the equipment manufacturing industry already exists or the Government considers the local equipment manufacture

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[5] ESCAP (1985a), p. 15.

[6] FAO (1985), UNEP (1985), HABITAT (1984).

[7] See reports of meetings held in UNIDO and ESCAP on energy capital goods manufacture, respectively, in UNIDO (1985b) ESCAP (1985b).

option for renewable energy technology diffusion in a broader industrial effort for capital goods production.

7. There is, of course, no general answer as to how the abovementioned advantages and disadvantages balance out. To start with, countries differ in economic conditions and resources endowment as well as in the extent of infrastructure development. The level of industrial and technological development achieved also varies widely, particularly when it comes to equipment manufacture.[8/] And, needless to say, this last would have a preponderant weight in such calculations. Finally, difference in development policy would also alter the calculations in a significant way. All this means that policy decisions relating to the role of local equipment manufacture need to be made on the basis of a specific set of conditions prevailing in the country concerned. Such an exercise would, however, benefit greatly if it were provided with information on the relevant experience of other developing countries. By limiting the range of technologies to be considered and defining the context of diffusion more narrowly, the value of such information may be made to increase.

8. The technologies to be considered in this paper are small-scale, requiring relatively small decentralized investments and less demanding technological requirements. As such, they are generally more amenable to local equipment manufacture in a greater number of developing countries than more complex renewable energy technologies, such as geothermal energy, fuel alchohol, or photovoltaics, that have much higher technical requirements and have economics of scale that usually lead to large centralized installations.[9/] The adoption of these technologies also requires that they be internationally transferred often in 'turn-key' contracts, with large capital investments and long lead times before the projects break-even. Table 1 summarises some of the attributes associated with these different scales of technology.

9. Another major difference of relevance between small decentralized technologies and large centralized ones is that the use of the former is more likely to lead to the creation of a domestic technological capability and to give stimulation to small-scale manufacturing industry. This capacity and infrastructure is necessary both for agricultural development and industrialisation.

10. Technologies considered in this paper are already used commercially in some locations. Solar water heaters, for example, are used in many countries throughout the world, with established markets in Israel, Japan, South Africa, the United States, and installations in many other countries including Papua New Guinea, China, Cyprus, Kenya and Zimbabwe. In Japan alone there are over 2 million solar heaters, while in the United States there are in excess of 200 manufacturers and 120,000 installations.[10/] Solar driers are also used

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[8/] See UNCTAD (1985) and UNIDO (1985a).

[9/] It should be noted, however, that technologies often do fit clearly into a centralized or decentralized category. Those with a docentralized energy supply may be relatively easy to install; but for some (e.g., photovoltaics) there may be considerable economics of scale in production.

[10/] For a discussion of solar water heaters see Bruggnik (1984), SIDA (1984) and Ward et al. (1984). Statistics for the United States are given in E.I.A. (1981, 1983).

Table 1: Some distinctions bewteen decentralized and centralized technologies

	Nature of the technology	
	Decentralized energy supply	Centralized energy supply
End-uses		
Mechanical power or electricity generation	Windmills, small hydro-turbines	Power stations supplying grid electricity
Heat	Solar heaters, wood heaters	Natural gas distribution
Transportation	(Animals)	Fuel alcohol, refineries
Investments	Small investments by individuals or groups	Large investments by utilities over long time periods
Technical complexity	Simple manufacturing and metal working	Often complex with 'turn-key' installations
Foreign exchange requirement	Generally low	Often high

in large-scale commercial applications in Argentina, Brazil and Israel, and for smaller applications drying figs, raisins and dates in Portugal, Greece and Turkey.

11. Both windmills and small hydro-turbines have been widely adopted, generally to produce shaft power either for agricultural activities or for generating electricity. Windmills are normally used for water pumping. They are manufactured in many regions and there have been windmill companies in existence for more than a decade in some ten countries (i.e., Argentina, Australia, France, the Federal Republic of Germany, Netherlands, New Zealand, Philippines, Thailand, United Kingdom and the United States).[11/] Argentina is the most significant developing country manufacturer, producing approximately 2,000 windmills per year, although other developing countries have younger and less-established industries. Small hydro-turbines are also used in many countries, the two most notable being China and Nepal. In the former, more than 90,000 small hydro plants had been installed by 1980 with a total capacity of 7.1 x 10^6kW.[12/] Most of these were sized under 25kW

11/ See IT Power (1983).

12/ Taylor (1982).

and it is reported that there are over 100 manufacturers producing more than 80 varieties with capacities as low as 0.5kW.[13] Nepal is an example of the recent creation of a market for hydro-powered agricultural processing equipment. There are currently at least four producers of hydro-mills in Nepal, the largest making some 50 units per year.[14]

12. In spite of these examples, the understanding of the working of the diffusion mechanisms for the above-mentioned technologies particularly in developing countries is quite limited. This paper constitutes an exploratory attempt to provide a framework for such understanding by combining the conceptual discussion of technology diffusion with whatever relevant empirical information is available. Although the paper focuses primarily on the role of local equipment manufacture as a diffusion mechanism, it is essential that first the demand aspect be considered, particularly in respect of the behaviour of the consumers or users and, above all, the factors that influence their purchasing decisions. While the discussion of demand applies equally to diffusion of imported or domestically manufactured equipment, it is of particular importance for the examination of the latter since the reliance on the latter mechanism may imply a greater need for the commitment of public resources in the form of support for the domestic capital goods industry. For this reason, in the next chapter, the question of demand for mature renewable energy technology is analysed. In chapter III different mechanisms for the diffusion are discussed, with a particular focus on the supply response of firms and the most relevant methods for the diffusion process. In chapter IV, policy implications are considered in relation to the possible role national Government can play to promote the diffusion and the areas in which international co-operation may be pursued to provide support to such national efforts.

13/ Personal communication of the author with IT Power.

14/ See Ashworth (1985), East Consultant (1982), Hurst (1986), UNCTAD (1984). Some information on the introduction of other new technologies is given in Khoju (1984).

Chapter II

THE DETERMINANTS OF DEMAND

A. Net benefits versus risks

13. Modern financial theory measures the attractiveness of an investment to an investor in terms of the expected profits and the riskiness of the investment. The level of risk is measured not only in terms of the uncertainty of the outcome of the investment itself, but also on the extent to which risks can be diversified away in the investors portfolio of other investments. Thus while other things being equal, more profit is preferred to less, projects that have more risks associated with them require a higher expected return, and the size of this expected return depends on the extent to which the overall profits of the investor are exposed by the project.15/

14. By analogy, if costs and benefits are measured in the widest sense to include non-financial attributes (e.g., prestige of ownership), then the decision of a consumer to purchase new equipment depends upon the expected attractiveness of the investment, and on the possible negative outcomes that may result from the decision to buy (i.e., the possible 'regret' at having purchased the equipment).

15. For example, the installation of a solar water heater by a wealthy household may be a relatively minor expenditure and the decision to install will depend on whether the financial benefits from reduced electricity consumption compensate for the inconvenience of installing the heater, and the associated worry of repair and maintenance.

16. Conversely, the case of a small farmer purchasing a windmill for crop irrigation may involve risks that threaten the farmer's basic well-being. Often simply adding irrigation water to existing farming practices may result in only modest increases in production. To yield the highest return, and indeed to cover loan repayments which may be significant relative to the cash earning of the farmer, he or she may have to start using "green revolution" high-yielding varieties of crops and apply commercial fertilizers. However, these new crop varieties may be very sensitive to water supply at certain times of plant growth - more sensitive than current traditional crops. Should the windmill fail at a critical time, it is possible that production levels may be severely reduced. In the extreme then, a small farmer purchasing a new windmill pump may face complete ruin if it does not perform appropriately; and under these circumstances it is to be expected that farmers will be very cautious about purchasing windmills unless they have a sufficiently large farm to guarantee a minimum level of income.16/

17. The use of a new technology involves a wide range of possible pecuniary and non-pecuniary costs and benefits. Non-pecuniary benefits include better quality control of the physical environment (e.g. hot water, space heating, lighting, etc.), and enhanced status in the community. Financial benefits

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15/ See for example Brealey and Meyers (1982).

16/ There is a large literature on the level of risk aversion of farmers. It has been argued that traditional farmers are in fact profit maximising given their resource endowments.

come from the savings on current expenditure resulting from the technology (e.g. reduced electricity consumption and reduced costs for agricultural processing) and any increased income (e.g. greater yields as a result of irrigation or the use of crop driers).

18. Financial costs are mainly associated with the capital spent on the technology, operating costs, and the payments for repair and maintenance. For some technologies cash may also be required to pay for other complements, such as fertilizers with irrigation pumps. The non-financial costs are mainly the labour of the purchaser and his household in operating the technology and managing its use. The effort required for a change in cultural practices can also be viewed as a negative attribute, often a very significant issue.

19. Social amenities, such as hot water for washing, are luxury items and the willingness to pay for them is highly dependent on income levels. In most low-income developing countries there will be relatively few groups who will attach sufficient value to hot running water to consider investing a significant sum of money in a water heating system. Consequently, the demand for solar heaters will normally be restricted to wealthy urban households, hotels, hospitals, apartment buildings, and some food processing industries. For these groups the diffusion of water heaters will be relatively simple if they are reliable and can be supplied at costs that make them financially attractive. Low income levels may strongly constrain demand, and even some commodities that might be viewed as basic, like a convenient and potable domestic water supply, may simply be beyond the resources of poorer groups without government subsidies.

20. Many possible risks may occur that influence the attractiveness of a technology. There is the chance that it may not perform according to its technical specifications, or worse of complete breakdown. Failures may vary in degree, as will the repair cost necessary to get the technology working again. There may also be uncertainty regarding the availability of the inputs necessary for operation, e.g. lubricants, water for hydro-turbines, etc. An example of how changes in factor prices can have drastic consequences is the gasifier programme in the Philippines. In this programme a parastatal company, GENCOR, was responsible for installing 242 charcoal fuelled gasifiers between 1981 and 1984. However, a survey in May 1984 of these gasifiers showed that 70 per cent were not operating. While technical problems were also a factor, a major element appears to have been the near doubling of charcoal prices in the three years up to 1984 from $50/tonne to $95/tonne.[17]

21. A major factor affecting the diffusion of windmills and hydroturbines is that both wind and stream flows vary with location and are stochastic phenomena. As a result of the variation in the availability of local resources (i.e., wind or water), there is the risk that at times they will not be sufficient to power the technology. For windmills used for pumping water,

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[17] Ashworth (1985), table 3.1. Similarly in China it is reported that more than half of the 7 million biogas plants installed with a relatively simple design are no longer in use, including 2 million which failed due to leakage. Care is required in interpreting these statistics, however. It may be that even with a short operational life investment in these technologies remained an economic decision.

this is particularly relevant, and large windmills with storage tanks may be required to ensure water supply.[18]

22. Uncertainty may also exist over the prices that will be obtained for the end-products of the technology where these are sold. For technologies (e.g., irrigation windmills, hydro-powered processing mills, and solar crop driers) that result in increased agricultural production, the ability of markets to absorb the incremental output may be a constraint. In rural areas, low incomes may restrict demand, and transportation facilities to move products to market centres may have a major effect on the demand for agricultural produce and, consequently, for new farm machinery.[19] For devices that yield non-financial benefits there may be uncertainty over future income and the ability to pay for these benefits, and for any technology there may be the possibility of a reduction in the costs of alternative methods of producing the same benefits.

23. There may conceivably also be risks associated with the influence of other members of the community. Particularly for technologies that require co-operation by joint owners or operators there is the possibility of the non-performance of partners, or of behaviour that undermines the expected returns. However, if the joint activity is among peers that can be relied on to work for common objectives, then co-operative ownership is a method of spreading both costs and risks.

B. The socio-economic environment

24. Earlier we have mentioned how many factors influence the attractiveness of a technology, and it is useful to categorize demand in financial, economic, or social terms.[20] In the first case, costs and benefits are measured in prices that actually exist at the current time, and this is the most relevant case for determining how people will actually respond. If actual prices of goods and services do not reflect their true benefits and costs to the economy, then prices can be adjusted in the calculation of the 'national' economic impacts of an investment. This then allows the Government to review methods of encouraging the use of technologies that are not necessarily fully compatible with its existing economic policies. Finally, in a social analysis, one also considers additional social objectives such as employment generation, income redistribution, etc.

25. Technologies can therefore be divided into: (a) those that are desirable based on a 'private' calculation of costs and benefits under existing resource endowments and government policy; (b) those that do not meet this condition, but for which there is a 'public' perception by the Government that they are

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[18] Bhatia (1984) notes how critical months of demand for power relative to mean windspeed occur.

[19] Pereira (1985) comments that transport co-operatives and transport facilities have proliferated in Nicaragua as a result of government incentives and intervention.

[20] These calculations do not include non-quantifiable benefits and costs such as status in the community, or required cultural change. These issues are discussed later.

economic in national terms; and, (c) those which are neither but are viewed by the Government or aid organizations to be socially desirable.[21]

26. Economic externalities, such as environmental degradation, are often not properly reflected in existing prices. Taxes and subsidies on many goods also move their prices far from their border value or long-run marginal costs, and so technologies which are economic may not be financially attractive. This is particularly the case for renewable energy technologies which usually replace a subsidised recurrent cost for diesel, kerosene, or electricity with a capital investment. Additionally, high import tariffs on imported materials (other than energy) may also increase financial costs prohibitively. Consequently, in order to make renewable energy technologies financially attractive it may be necessary to give them subsidies.[22] It should also be noted that, whereas a subsidised price for kerosene for certain groups pervades all uses for kerosene, it may be relatively easy to tie capital subsidies to a particular piece of equipment.[23] Technologies that are neither financially, nor economically feasible by definition require government subsidies if they are to be used, or alternatively, the costs of the technology may be covered by an international aid organization.

27. Clearly, the cost of buying equipment depends crucially upon the cost of capital to the purchaser. However, the access to credit may be very unequal, and the poor who usually need credit more often, typically get less of it at least from government sources, and as a result pay more for it.[24] Table 2 shows, for example, the actual average interest rates available to farmers in India; the rate (for all sources) almost doubles from large to small farmers due to the latter's lack of access to more favourable sources of credit and heavy reliance on money lenders. As Hurst (1985, p. 108) notes in addition: "the marginal rate of interest may increase rapidly for smaller farmers, as extra credit is not available to them from commercial banks or government sources, and they must rely on moneylenders".

28. The cost of credit from such private sources may be very high, in terms of not only the interest rate, but also the consequences of a default. In some areas there are still families essentially in bondage to wealthier households due to debts accumulated by their forbearers. Poorer households may therefore prefer technologies which have relatively lower capital costs and higher annual costs. The argument has been made that capital intensive

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[21] It should be mentioned that socially optimal technologies can also be both economically and financially attractive.

[22] There is, of course, a theoretical possibility of changing domestic prices to reflect their true economic value (e.g., higher price for kerosene to cover the full cost of delivery to the consumer) and meeting other objectives, such as social ones, through income taxation and a social security system. However, this is often not a politically feasible option.

[23] Any subsidy should be linked to the performances of the equipment. In the United States tax refunds on solar water heaters range from 5 per cent to 50 per cent depending on the State (Solar Age, 1985). However, in all States but Oregon the tax incentive is not linked to performance.

[24] See, for example, Singh (1979). In some countries the access to credit has been expanding due to Government programmes.

Table 2: Interest rates by farm size and source of credit in rural India

(per cent)

Size of holding (ha)	Government	Co-operative	Commercial banks	Money lenders	All sources
0-2	8.9	8.9	7.2	22.5	16.0
2-4	9.0	9.1	8.1	20.9	14.3
4-6	8.3	9.0	9.4	23.3	14.9
above 6	8.4	9.0	9.2	16.3	9.0
Average	8.8	9.0	8.4	21.8	14.8

Source: Singh, (1979), table 5.4

projects are preferable because farmers cannot guarantee the availability of cash for recurrent costs. However, the distinction between loan repayments and other forms of cash-payments is quite arbitrary.25/

29. Social constraints to the adoption of a technology can also exist, and in some instances may be more binding than the economic issues discussed above. These can be a matter of preference, or the result of the influence of the community. For example, there is a taboo in parts of India on handling human faeces, or on cooking with biogas produced from this source, while in China it is a common practice to add human faeces to the biogas feedstock. Similarly, the use of solar cookers may be perceived as disadvantageous by some potential users if they require a change in the time when food is cooked, or require the cook to be in the sun for long periods. In such instances it is unlikely that the benefits perceived by users would outweigh the costs sufficiently to compensate for the cultural change required.

30. It is also the case that as members of a community the behaviour of an individual can be strongly influenced by that of the dominant social hierarchy. This is particularly the case for technologies that are communally owned.26/ A lack of co-operation has had a major effect on the performance of community biogas plants in India.27/

25/ Of course, if the technology is donated, the more significant the capital costs, the less resources the farmers will need to operate it. All new technological acquisitions cannot be the result of gifts, however.

26/ See Hurst, (1986, p. 7).

27/ See Lichtman (forthcoming) for an account of the organisational problems with community biogas plants. There are, of course, exceptions. In Padma, India, for example, a local organisation has set up biogas plants which use human faeces from a community toilet as feedstock to generate electricity for street lighting, in the process bypassing any possible cultural constraint mentioned earlier as well.

31. The control of resources by minority elite groups can be reduced by the involvement of grass-roots organizations. These organizations, often non-governmental, can provide an unbiased source of management for projects; unfortunately their scope is often restricted by constraints on manpower and funds.[28]

32. Social inequalities, most importantly a sexist bias against women, also exist within the household and may affect investment decisions.[29] Thus, the actual demand for technologies that are beneficial primarily to women may be less than would be the case if women were to control the household finances. These social constraints can be overcome in the longer term by education, and in the short run through subsidisation of the relevant technologies. This is an area of political decision by the central Government, and depends on the social awareness and priorities of government institutions.

33. If a technology is to be subsidised for social ends it may be very difficult to ensure that only the socially desirable activity benefits from the subsidy (the classic case being subsidies on kerosene for poor households that are realised by all consumers). Even for a technology which is only appropriate for use by target groups there may still be problems. For example, hand pumps are a suitable method of irrigation for small farms, but are not cost-effective for larger farmers due to their capacity restrictions.[30] However, many small farmers are sharecroppers, and their farm equipment is often owned by the land owner rather than the operator. Mandal (1978) reports in Bangladesh how sharecroppers had to pay one-quarter of their gross output as rental for hand pumps supplied by large farmers. By analogy, subsidies on technologies may simply allow those with access to capital - the wealthier groups - to purchase the technology and then rent it to others, at prices such that the owners obtain most of the benefits.[31]

34. In the earlier discussion, the element of uncertainty introduced due to possible breakages of equipment was noted. The ease of repairing and maintenance depends upon the technical knowledge of the owner (for minor repairs), and the access to trained personnel (for major ones). There has been the misconception by some aid organisations that, because some renewable energy technologies are capital intensive, one method of getting them to the users is simply to donate equipment. Even though these technologies may be simple, their use, in particular repair and maintenance, may nonetheless be beyond the skills of the population to whom the equipment is destined. Under such circumstances merely shipping in the equipment is doomed to failure unless there are also adequate training programmes and inventories of spare parts. Renewable energy technologies may therefore require as much contact with the modern sector as any other, and the fact that a renewable source of energy is used will be a rather arbitrary classification in many cases.

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[28] Such organisations have many forms, and some research on the relative effectiveness of different types of organisation would be useful.

[29] These inequalities are discussed in more detail by Agarwal (1983), Cecelski (1984), Smith (1985) and UNCTAD (1985a).

[30] See Hurst (1985).

[31] Competition between wealthy groups to supply technology may also be very limited.

35. From the foregoing discussion it will be clear that many of the factors likely to positively affect the demand for mature renewable energy technologies in rural areas - technical training, transportation infrastructure, improved communication with urban areas, etc. - are addressed in a co-ordinated manner in programmes of intergrated rural development. Increased incomes resulting from such programmes would also be expected to stimulate the demand for such technologies. However, it does not necessarily follow that integrated development programmes will lead to their diffusion; this will still depend upon the financial attractiveness of the particular technology to potential consumers, although presumably smaller incentives would be required once additional infrastructure is in place. Moreover, while the introduction of a renewable energy technology may provide a useful basis for organizing rural populations, the key issue in general development programmes is not energy availability per se, but more the implications of low incomes, shortages of savings and credit, and lack of access to the modern sector.

Chapter III

DIFFUSION MECHANISMS

A. Interactions between actors

36. While a demand must exist for a technology for its diffusion, clearly someone must also supply the technology, either by importing it or by making it locally. Indeed, for a technology to be used a complex network of separate economic actors may have to be involved. We have already discussed issues that affect the investment decisions of purchasers, but the producer of the technology, possibly a distributor, and a source of finance must all take part for the technology to be diffused.

37. Figure 1 is a schematic representation of the interactions that arise with the development of a new industry for the diffusion of a technology. The source of finance is perhaps the most important element in affecting the feasibility of the system, since both the purchaser and the producer generally need to borrow money, either in order to buy the product, or establish the means of supplying it. Funds can come from a variety of sources; they can be provided by the Government, by commercial banks, or by private individuals. In the case of the producer, investment may additionally be available from other companies, both domestic and foreign, as part of a joint venture. The producer can also take a variety of identities. Equipment may be made by a whole range of organizations, from small rural workshops to large factories. Often the consumer will not have direct contact with the manufacturer, but will learn of the technology, and obtain it from an independent distributor. The final element to the system is some form of repair and maintenance facility which will be available to keep to technology working for the consumer and have access to the producer for spare parts and technical information.

38. Five separate types of actor are illustrated in figure 1, although it is possible for a single entity to take on more than one of these roles. Rural workshops for example may be both producer and distributor, and undertake repair and maintenance. For community level projects, the community may organize the fabrication of the technology, and so take on all of the activities. Large companies may be able to cover the costs of establishing new manufacturing plant without borrowing money, and may even arrange financing for prospective customers (although usually through collaboration with a bank). The Government can also adopt the role of any one of the actors, including the consumer. The production of equipment can be done by State-owned companies, the distribution of equipment may be through government extension services, repairmen and repairwomen may be directly trained and employed by the State, and credit can also be provided. The important factor in the stability of the market is that each of these five activities must be undertaken by some institution which implies that the benefits for each actor must outweigh the costs, and must at least be as attractive as other options.

39. The above discussion has been somewhat simplified as we have only described a static situation. In the absence of existing markets, however, the spreading of a 'new' technology will require dynamic interactions between the actors. This dynamic process leading to a stable market can be thought of as the process of diffusion, and it will be apparent that there is an infinite variety of paths that it is possible for a technology to follow. The following discussion will focus primarily, though not exclusively, on the role the domestic equipment manufactures may play in this process and the factors which determine this role.

B. Rural production

40. The optimal type of supplier for a technology must of course vary from case to case. Although most purchasers of solar water heaters would be expected to be found in urban areas rather than rural ones, the reverse is true of windmills, hydro-turbines and solar crop driers. For these latter technologies there may therefore be some advantages to rural production: both consumer and producer would then be located geographically close to each other and distribution and repair costs could be much reduced. Economies-of-scale associated with larger companies can often be compensated for by using different manufacturing processes without necessarily a loss of product quality. However, the supply costs of raw materials are obviously increased as is the difficulty of rural workshops accessing design material, and technical knowledge.

41. Community level projects, such as village electrification with hydro-turbines, are another option. The feasibility of these projects depends upon the ability to efficiently organize local manpower for construction and operation. This may be a problem in many locations. It will usually be the case that the equipment and installation costs for community projects will be met by the central Government, although the local population may be able, or can be co-opted to help with the necessary earthworks and construction.[32/] Organizing maintenance, operation, and tariff collection at a local level will be a major hurdle, and may require assistance by grass-roots organizations. A commitment from the central Government to support these groups would be required if this is the case.

42. While small rural workshops and artisanal manufacturers can imitate existing equipment, and even invent their own technologies, obviously the number of consumers that can be catered for by any one workshop is obviously quite small. Government involvement is usually also restricted to more indirect activities, although credit schemes and technical training are areas where public programmes could yield large dividends. The products made in rural workshops may also be of inferior quality and insufficiently reliable to create widespread demand. Provision of improved designs and testing of products by public research institutes and technical extension services may go a long way to alleviate such a problem.

43. Experience shows that mechanical production in developing countries can develop over time out of imitative production at rural workshops and repair shops in the non-organized sector (UNCTAD, (1985); UNIDO (1985)). This, however, would depend on a whole host of factors, particularly on the demand side. Such a development cannot be expected to take place on the basis of demand for renewable energy equipment alone. Furthermore, it would also require some ties with the organized mechanical industry for technical knowledge and some intermediate inputs. For producing such equipment domestically, therefore, it may be more desirable to think in terms of factory production.

32/ In a programme of village electrification with micro-hydropower in Thailand, the villages are reported to have contributed 10,000 man-days in one case (Ashworth, 1985).

C. Modern factory production

44. The rural workshops discussed above usually have few employees and limited access to machine tools, although some may have lathes and mills. Naturally there will also be a range of manufacturing enterprises of greater complexity in existence from small firms (employing up to 100 workers) that tend to manufacture in job lots, to large-scale continuous production with extensive divisions of labour. These firms are generally found in urban areas, and have a higher level of technical competence than rural artisanal workshops.[33/] Because they are larger they are also more integrated into the industrial and financial sectors.

45. When considering the possibility of entering new markets such firms weigh different objectives including potential profits, their potential market share for the new product, and the current status of markets for other goods. Companies are not uniform and vary dramatically in size, resources, and organization; and the extent to which generalisations are possible is limited. Some firms may actively encourage R&D, and aggressively look for new profits in new markets, while others may take a more passive approach in the belief that they are currently obtaining sufficient returns.

46. Individual firms operate within an economic system that requires interactions with other companies and their behaviour depends upon their perceptions on the availability of power, transportation, equipment, etc. Indeed, once the production is initiated, defending a current market niche may require all the resources of the firm to manage deficiencies in the factor markets and supporting services sector. To quote Singh (1985, p. 36): "Rather than conduct R&D the small firms in LDCs are more preoccupied with solving the basic problems of day-to-day survival by organizing adequate and/or alternative supply of raw materials and working capital".

47. Firms must also take account of the behaviour of their competitors. If they are heavily involved in some new activity this may weaken the response of the company to intensified competition in its current markets. A firm nurturing an infant market must consider subsequent rivalry in that market by new entrants. Given the uncertainties of selling a new product, companies may be reluctant to commit funds to development of such products unless it is possible to limit later competition.

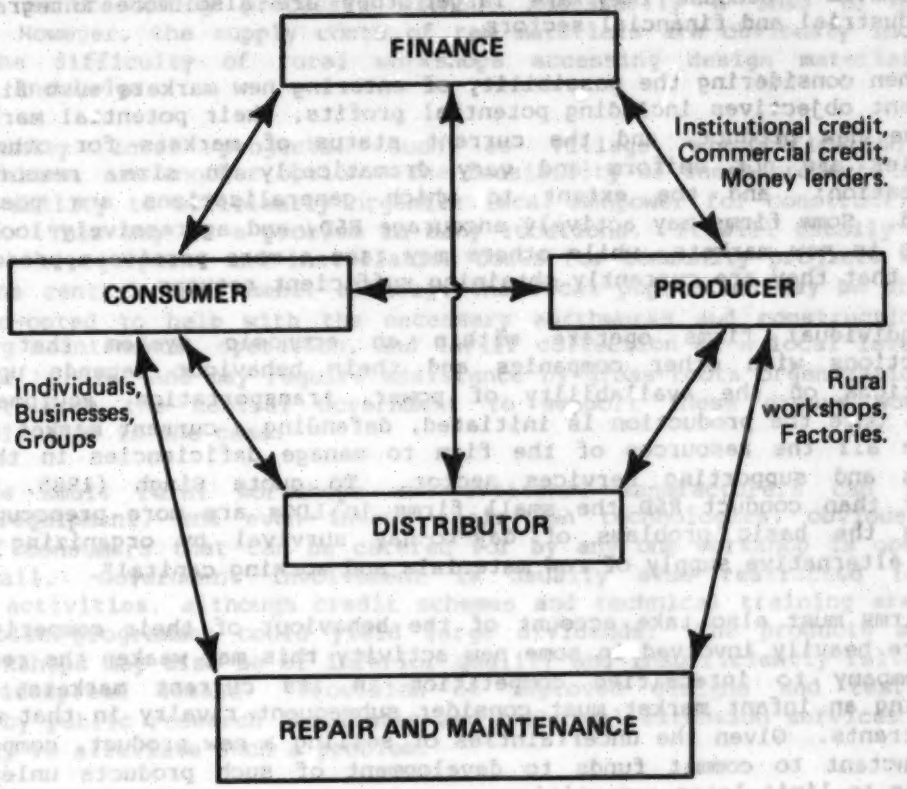
48. In many low-income developing countries there are often small markets for the kind of manufactured goods considered here, with few firms involved in their production. High import tariffs may also restrict foreign competition with the result that there is not much rivalry between firms. The effect on the behaviour of the firm of infant industry protection policies or oligopolistic markets is far from clear.[34/] Some argue that most innovations in developing countries are reponses to crisis (e.g. loss of market) and propose that protected markets dampen the innovative behaviour of firms.[35/] However, removing protection increases uncertainity and thus may also reduce innovative behaviour.

[33/] Some urban areas can be very remote, however.

[34/] For a review of empirical information, see L.E. Westphal, 1981. See also M. Fransman, (1985) which looks at protection in a broader context of the discussion of technological changes in developing countries.

Figure 1

The diffusion framework



49. Competitive industry can also lead to more efficient operation and to product innovation from incentives to maintain profits, but it may also imply problems for maintaining market share for a new enterprise. Products are difficult to protect unless they have a particular production process that can be kept secret. The simple technologies under consideration are easily imitated, and it would be possible to make design adjustments to avoid the weak patent restrictions in existence.36/ A large demonstration effect may also be expected and in a competitive environment many firms will start making similar products if the market proves fruitful.37/

50. Innovators in markets usually expect the inherent risk associated with a new product to be compensated with increased profits from a rent on the technical knowledge embodied in the new commodity (i.e., additional profits as a reward for technical creativity).38/ If it is not possible to meaningfully patent the product, then the increased profits will be removed by competition. For a firm intent upon innovation, there are two main strategies to combat this stalemate. One is for the firm to make the new product on a small scale for a minimum of costs. In this case links between the new and existing technology, the availability of space near old plant, and the possibility of integrating old and new production processes (e.g. using existing equipment) will be very important. With this approach the lack of a high profit for a risky investment is reduced by minimizing the magnitude of the commitment to the product. For the economy as a whole, however, this is clearly a less than optimal situation.

51. A second strategy is to enter the market on a large-scale with mass production and extensive advertising to generate a guaranteed position of dominance for the firm.39/ This strategy requires large investments, and it is most probable that the same strategy can be applied on other more conventional products, probably with a greater likelihood of success. For larger undertakings the deficiencies in the supporting services may become even more binding and their perception of such risks that much greater. There is also an administrative overhead in organizing the small-scale production of a new product in a large organization where there are divisions of labour.40/ Therefore, in markets where there is any degree of

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35/ See, for example, Bell (1984).

36/ The patent system in developing countries is discussed by Wantanabe (1982).

37/ Studies show that diffusion is more rapid in a competitive economy (Kamien and Schwartz (1982), p. 102).

38/ These technical innovation rents are therefore quasi-rents rather than pure rents.

39/ This is in effect an attempt to replace the expected rent on technical innovation with a monopolistic rent.

40/ A detailed survey of firms in Thailand, Indonesia, and the Philippines, for example, shows that the management of labour is generally not a problem as long as the production processes remain relatively simple and small-scale, and require no precise co-ordination of the work of many employees with specialised skills. Ichimura (1983), p. 72-73. For a discussion of the organization of capital goods production and problems developing countries often encounter in this respect, see UNCTAD (1985 b).

competitiveness in the manufacturing sector there is a clear economic logic to expect that, without Government involvement to reduce the uncertainties inherent in creating a new low-technology market, initiation of large-scale equipment production will be difficult, and at any rate, the first entrant is unlikely to be a new mass-producing factory.41/

52. As we have noted, factors may vary from region to region that make this generalization less applicable. The perceived size of the market is of course important for the creation of large-scale producing industries. A rapidly growing demand for end products of a given technology (e.g. hot water, irrigation) will favour the supply of a new technology. Rapid growth in the economy also introduces a dynamism, which allows for the more frequent movement of capital and skilled labour, and encourages experimentation.

53. Of course it is not necessary that complete manufacture be restricted to one particular type of firm. Components can be fabricated industrially and then assembled in rural areas, for example. The situation can also change with time, and a large factory producing a certain type of equipment may later allow small companies and rural workshops to enter the market by copying and adapting the design (such as happened with diesel engine production in Pakistan; see UNCTAD, (1985)). As noted earlier, one might also foresee a situation where small producers establish a market of sufficient size to allow large-scale production, possibly by undermining the markets of existing producers. Components can also be imported from foreign companies, as can the complete product. Even then, once local equipment manufacture is initiated, as much of the value-added as possible should be captured domestically (and foreign exchange costs minimized), and as much local fabrication as is practicable should be encouraged. However, this is not always easy; for example in an African setting it has been observed that locally-produced solar collectors cannot compete as to either cost or quality with imported versions.42/ Similarly in Papua New Guinea, the domestic manufacture of solar water heaters has been almost completely displaced by $4m^2$ collectors imported from Australia.

54. The role of imported technology depends on domestic technical capabilities, the complexity of the technology, and the availability of foreign sources. For the simple mechanical technologies under discussion there is usually reasonable scope for domestic activity. This, of course, is not to argue that for these technologies local equipment manufacture is always a superior alternative and that equipment import has no role. Far from the latter, imports through commercial or non-commercial channels are in reality the primary supply channel in developing countries - sometimes even to the detriment of the local equipment industry. Dependence on imports is especially prevalent with more complex technologies, such as large-scale ethanol production or photovoltaic array assembly. Even in such cases, however, there is scope for technology unpackaging, depending on the domestic technological and industrial capability of the country concerned. To the extent that such capability may help reduce foreign exchange constraint (for

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41/ This is contrary to the hypothesis (Schumpeter (1939)) that larger firms are more important agents of innovation because they have more resources to exploit the results of innovative activity. The hypothesis that small firms will be the major innovators is strengthened if they are more efficient at conducting R&D as had been observed in some developed countries.

42/ Ward et al. (1984).

example, through local manufacture of part of the equipment involved), this could hasten the pace of diffusion.[43]

D. Access to design information

55. The previous discussion assumes that the innovative producer has access to technical information on a new product, and there are a wide variety of possible methods to access this information. The producer can independently develop new technologies based on its own research, or can adapt existing designs. Alternatively, at a certain scale technical knowledge can be transferred from foreign sources under licensing agreements, with foreign investment, or through outright purchase.[44] Table 3 gives a summary of the most popular sources of information used by businesses in the Philippines, Thailand, and Indonesia. Informal channels for transmission of technical knowledge, such as through contacts with trading companies and machine suppliers, trade journals, travel abroad, fairs, etc., are found to be important for much of standard capital equipment, although it is not clear whether this should be the case for new and innovative technologies.

56. For the kind of equipment considered in this study, the product designs can be indigenously generated by internal R & D or through imitative

Table 3: Eight most frequently used sources for gathering information on new technologies

	The Philippines	Thailand	Indonesia
1.	Trading companies	Trips abroad	Machine suppliers
2.	Machine suppliers	Machine suppliers	Trips abroad
3.	Parent companies	Magazines	Associated companies
4.	Associated companies	Parent companies	Magazines
5.	Magazines	Trading companies	Domestic trade fairs
6.	Customers or buyers	Associated companies	International trade fairs
7.	Trips abroad	Customers or buyers	Television
8.	Trade journal	Trading companies	Government services

Source: Ichimura (1983), p. 17.

43/See Stuckey and Juma (1985).

44/For a discussion of the means of technology acquisition in the capital goods industry, see UNCTAD (1985).

manufacture trials. Design information can also be supplied by foreign firms either accompanying investment or through technical collaboration arrangements. An example of how the licensing of technology can lead to the creation of a domestic market is that of the Argentinian windmill industry. Although windmills had been imported and some crude reproductions made locally in the 1940s this was only on a limited scale. Then in the 1960s, the Aeromotor Company of the United States made an arrangement to manufacture their windmills under licence with Fábrica de Implementos Agrícolas, S.A., an Argentinian manufacturing company making Fiat engines (also under licence) and small farm machinery. The main motive for the former was to reduce costs for supplying windmills for the United States. The financing of the manufacture of the windmills was entirely by private capital, with technical assistance from the United States company. Windmills were exported to the United States with stringent quality controls on the components by the importers. Over a period of years, the manufacture of windmills became the major activity of the Argentinian company, and a domestic demand for the technology also developed. The lack of patent restrictions, and a perceived demand for the windmills led many small firms to imitate designs. Today Argentina produces approximately 2000 windmills per year, or one fifth of world production.45/ Although Fábrica de Implementos Agrícolas still maintains a 50 per cent market share, there are now more than 20 other manufacturers involved.

57. However, for the kind of technologies being discussed in this study, the interest of foreign investors may be rather limited on the one hand because of the difficulties any firm would face in this area (as discussed in the preceding section) and on the other hand because the firms which own such technologies are generally small-scale manufacturers whose capacity to assume risks (e.g., for overseas ventures) is quite limited.46/ The situation may, of course, be different for some technologies, such as solar water heaters or the sophisticated end of mature technologies (e.g., wind-electricity) which are widely used in several developed countries, that have export market potentials in developed countries.47/ In this case, however, domestic diffusion of the technology in the developing country concerned would have to be worked out separately unless it is 'planned' as a

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45/See IT Power (1985).

46/For a discussion of these and related problems which small- and medium-sized firms from developed countries face in the transfer of technology, see UNCTAD, "Major trends in international transfer of technology to developing countries by small- and medium-sized enterprises" (forthcoming).

47/Another product with such export potential from developing countries is photovoltaic arrays. Although photovoltaics technology as such is new and still evolving with the development of materials technology, should photovoltaic cell production costs fall to a level where they have significant international markets, then it is possible that cells could be assembled into arrays in developing countries, as is the case with electronic components in some developing countries. A certain proportion of arrays could then be exported in order to 'ensure' the interest of foreign companies, with the remainder being sold on domestic markets. See UNCTAD (1986c).

spin-off.[48] If the size of the domestic market in developing countries is large, there would be a correspondingly larger scope for foreign investment. This would also give concerned additional options for technology transfer to the developing country.

58. The problems of risks for the foreign technology supplier can be overcome by a one-time payment for the purchase of technical information and machinery, or if the costs are covered by export credits provided by the government of the supplier's country. In this latter case, however, the developing country concerned may have to accept certain constraints on the choice of technology. In an analysis of power alcohol production in Kenya and Zimbabwe, Stuckey and Juma (1985) note how the availability of export credits can influence the technical choice and lead to technologies that are not appropriate for local conditions. In Kenya, the ethanol plant was financed by foreign export credits with the consequence that a technically complex, capital-intensive design was chosen from a supplier in the country providing the credits. By contrast, in Zimbabwe local capital was used, and a more simple and appropriate ethanol plant was bought. This is, of course, not to argue against the use of export credits, but to illustrate the factors which may constrain the technical choice by developing countries.

59. It is indeed possible, however, that any technology from abroad may have been designed for a different set of economic and physical conditions and, for this reason, is inappropriate for use in developing countries.[49] In Africa, for example, the attempts at diffusing windmills have encountered problems: in addition to lack of spare parts and maintenence, there have been design problems. Particularly designs do not appear appropriate for low wind speeds; nor do they have sufficient safety features to shut them down in hurricanes and typhoons.[50]

60. Technical knowledge and designs can be transferred into a country by governmental research and development institutions and universities. However, there have been problems in many cases with this route, due mainly to ineffectual communication between formal research institutes and those whom they are meant to serve. Part of the problem is one of philosophy. Engineers working for a commercial company treat technical information as a private good and attempt to maximise the private rents (i.e., additional profits) from this knowledge. The staff of research institutes have different objectives, and treat their information as a public good which should be freely disclosed to all. Indeed, the salaries at such institutions are often modest, and the staff is highly motivated to produce scientific knowledge for non-financial incentives.[51]

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[48] It is interesting to note that the reverse of this may be taking place with wind-electricity technology in India. The Indian Government has recently concluded agreements with a few Danish manufacturers of wind-electricity equipment for supply of a demonstration/testing project. In the process, Danish manufacturers involved in negotiation became interested in the possibility of a manufacturing arrangement with an Indian equipment manufacturer to supply the European market.

[49] See Stewart (1977), Binswanger and Ruttan (1978).

[50] WARD et al (1984).

[51] See Dasgupta and David (1985). This was first discussed by Arrow (1962).

61. This is extremely laudable, but poses a dilemma for the firm using designs from these sources. Not only is the complete specification of the technology available to any competitor, but there is also the possibility that the research institute will subsequently produce a better design which will also become public knowledge. This may not be a problem if the initial firm can rapidly adjust its own designs, but the added risks do nothing to add to the security of the innovating firm. It follows from the earlier discussion, that information of this type is more likely to be of use to small-scale producers. However it is these groups that often have less contact with R & D institutions, and are potentially lacking in the capacity to supply the technological services that are complementary to R & D.52/

62. Another problem is that the research at formal institutions is sometimes not directed at real world problems. In reviewing the work of research on farm equipment in Bangladesh institutes, Jabbar (1985, p. 13) observes:

> "The idea of new design came mostly from the thought that improved farm implements were essential for agricultural development. [It was assumed that] all production problems had an engineering solution and farmers would be interested to use improved implements if suitable designs were available. The researchers hardly ever thought of going to the farmers to ask whether they wanted any improved implement to solve any particular problem."

In Jabbar's survey he identified 20 different types of equipment design that had been modified and adapted by the R & D system. None of the prototypes of any equipment designs had originated from formal research organizations: all had been developed by private firms or individuals. This is perhaps an extreme example, but clearly illustrates that while such institutions can be helpful in demonstrating the technical feasibility of designs to both consumers and producers, through inappropriate research or perhaps more significantly through a lack of appropriate communication, they may have a minimal catalyst effect. More active interactions may, therefore, be required between the institutes on the one hand and the producers and consumers on the other.

E. Distribution of technology

63. Even if there is a potential demand for a new product, and a supplier of one form or another is interested and has the necessary information and capabilities to produce it, some type of distribution network is also required to link supply and demand. For consumers in urban areas this may be relatively easy with an existing network of retail outlets operated by the producer or independent retailers. There is also an existing mass media to communicate information on the new product to consumers.54/

52/ This latter point has been corroborated by an observation of a National Energy Administration (Thailand) official that the main bottleneck for the commercialization of the output of R&D institutes is the lack of proper drawings and documentation. The institutes provide only prototype demonstration devices and the prospective manufacturers are unwilling to commit on that basis.

53/ See Carr (1981).

54/ Agarwal (1983) notes that the mass-media is often elitist, and may not communicate with the poorer sections of the society.

64. In rural areas, or small urban areas remote from regional centres this may be more complex, and depends upon the nature of the technology and type of manufacturer. If the relevant equipment is made in rural workshops the manufacturer will most probably be able to deal personally with sales of the product, and this is one advantage of rural production over centralized mass production. The value of a degree of direct contact between producer and consumer is also strongly influenced by the possible evolution of the technology, and its potential for local adaption.

65. Consider the example of the diffusion of an improved wood-stove.55/ The wood-stove is a simple technology, but one that has a complex range of attributes such as efficiency, flexibility in the use of fuels, flexibility in heating rates, ability to provide space heating, and pest control from smoke. These attributes have intricate trade-offs and the stove designs can be adjusted at moderate cost to give different combinations. The technologist attempting to improve the functioning of traditional stoves (often a Western or urban male) may have little contact with the potential customer (often rural women), and it is not surprising that most stove programmes have had limited success. Under these circumstances, the 'bottom-up' diffusion suggested by Agarwal (1983) may be essential, where the final form of the technology is determined by close interactions with the final users. A similar argument can apply to the diffusion of improved farm implements, where fully understanding the many complex attributes of, say, a plough is essential if it is to be improved.

66. However, for other technologies, the potential for adaption may be extremely limited or non-existent. While an extensive organization may still be necessary to persuade the consumer to purchase the technology, the philosophy of diffusion becomes one of information delivery, and persuasion.56/ This will be the case for most designs of hydro-turbines, windmills, and solar water heaters. For these technologies, adaptations by rural artisans may be important and cost reducing, but will more likely involve minor changes in components to account for local resource endowments. An example is the practice in Northeastern India of the replacement of the metal pipe used to line a tube well with bamboo: although the life is shorter the capital costs are reduced significantly.

67. Solar driers can be made very simply, and have more scope for rural artisanal manufacture. However, most solar driers intended for small-scale rural producers are in the design and development stage, and there have been problems in making them cheap but reliable. Artisanal fabrications with local materials have not had sufficient robustness or good enough seals, while metal framed designs are considerably more expensive.

68. For mass produced technologies, the general philosophy of marketing will be that of a 'top-down' information diffusion.57/ Indeed a similar conceptual approach applies to the transfer of designs to potential rural producers. This 'school' of thought is summarized by Agarwal (1980, p. 48):

55/ There is a large literature on the wood-stove. See Agarwal (1980, 1983), Foley and Moss (1983), Foley et al. (1984), Pereira (forthcoming).

56/ See, for example, Rogers (1977).

57/ Birth control is the classic example of this.

"This [diffusion process] takes the need for the innovation and its attributes as 'given' and concerns itself primarily with the process of communicating information on pre-developed innovations to the final users. In so far as the potential users recognize the need for this innovation; the process of diffusion reduces to arranging an information delivery system ... However, for those that do not recognize the need ... the diffusion process would also require overcoming their "scepticism" and "persuading" them to change their "attitudes". Here the role of informal personal communication channels (the "network") is seen to be primary, as is the role of the "change agents" and "opinion leaders" within it."

69. Naturally, if the technology is not suitable for use by the targeted consumer group the diffusion effort is doomed, and this is certainly one of the reasons why some programmes of technology dissemination have failed in the past.

70. The process of information communication may require "grass-roots" organization in order to help prepare people. An example of how personal information can be instrumental in creating a demand for new technology is the Nepalese water turbine programme. Here an apparently stable market has been created with essentially no subsidies.[58/] In this programme site evaluations for potential purchasers were carried out by the Appropriate Technology Unit at Tulispur,[59/] and by the Development and Consulting Services of the United Mission, a non-governmental organization, to Nepal. Although initially consultancies were provided free, a fee has subsequently been introduced. In the case of the Development and Consulting Services, a charge of Rs 200 ($11.3) is made, with an extra fee of Rs 1500 ($90.4) being charged if the site is suitable for a turbine.[60/] The receipts from these fees are apparently sufficient to cover expenses during the preliminary surveys of both feasible and non-feasible sites. The specialist teams responsible for both the site evaluations and for installation of the turbines also act as an intermediary between the purchaser, the bank, and the manufacturer. Furthermore, the manufactures themselves are involved in information dissemination.[61/] Table 4 gives a summary of the level of investment involved, and the relative contribution made by the purchaser's own capital. Loans were made available from the Agricultural Development Bank of Nepal at an interest rate of 12 per cent over a repayment period of five to seven years.

71. It is possible for the Government to provide assistance in information communication through its technical extension networks. However, the use of government extension services as they exist currently may be insufficient. Many extension officers seem to be inadequately trained, are regularly

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58/ See Hurst (1986), Ashworth (1985), East Consultant (1982), and UNCTAD (1984).

59/ The Appropriate Technology Unit was established in 1981 by the Agricultural developmenet Bank of Nepal with financial aid from USAID (Khoju, 1984).

60/ East Consultant (1982).

61/ See UNCTAD (1986d).

Table 4: Investment costs of selected hydro-turbines in Nepal[a/]

Capacity of turbine (kW)	Installation date	Installation cost (1000 Rs)	Total capital cost[b/] (1000 Rs)	Purchasers' capital (1000 Rs)
1. 17	1981	66	92	42
2. 15	1979	39	73	18
3. 12	1981	37	78	26
4. 9	1980	39	129	48
5. 11	1980	42	101	51
6. 21	1979	37	87	37
7. 9	1979	24	53	13
8. 6	1980	30	38	10
9. 17	1981	58	108	49
10. 13	1981	44	64	14

Source: East Consultant (1982).

a/ Exchange rate in November 1984: $1 to Rs 17.7

b/ Includes the cost of processing equipment such as a rice huller, grain grinder, and oil expeller.

transferred, and have low rank in the administrative hierarchy. They are said to prefer to deal with elite social groups, and are sometimes placed in the position of not having the authority to deal with the demands made of them, and of being unable to fulfill their promises.[62/] This can lead to loss of confidence by target groups.

72. Because the performance of windmills and hydro-turbines are very location specific, it is important that the personnel responsible for site evaluation of these technologies are well trained. For any technology where reliability is of prime importance, trained specialist installation teams may be necessary. Even for a simple technology, such as a solar water heater, using incorrect lagging material can lead to corrosion and leakages.

73. The uncertainty of being able to generate markets for new products outside of urban areas will be major concern to urban suppliers, and in rural areas simply the geographical dispersion of consumers increases costs. In the first instance, the easiest markets to create will be those for wealthier consumers. It may be necessary to target these groups initially in order to build up the supply infrastructure that will make the latter more widespread diffusion of the technology possible.

74. Companies are likely to manufacture new products only if there are existing reliable distribution networks through which the technology can be disseminated. An alternative is for a reliable distributor/retailer to contractually guarantee the purchase of a given number of the product, and to assume all the risks associated with distribution. This is one role that the Government may adopt, and will be discussed in more detail in the following section.

62/ Indeed, extension officers may even require training to correct their existing false notions (Singh, 1985).

Chapter IV

POLICY IMPLICATIONS

A. The role of government

75. The question of the appropriate role for government in the diffusion of mature renewable energy technology, must naturally relate to the large question of the role of government in the economy generally. It should also be considered in the broader context of the energy sector development. This paper has identified several arguments why markets for certain types of such technologies may not evolve and domestic equipment makers may not develop as an effective diffusion mechanism without government involvement, and why intervention to manage the diffusion process may be essential if widespread application of such technologies is desired. This chapter will discuss different policy instruments which the Government has at its disposal in a mixed economy for implementing a deliberate promotional policy axed on domestic equipment manufacture.63/

76. Table 5 presents a summary of policy instruments in relation to areas of government involvement as well as to the particular actors to whom they are addressed. The stance of the Government, which may range from a minimalist approach to one of strong interventionism, may be defined in terms of the ways these different instruments are combined.

1. Information to consumers and manufacturers

77. One fairly fundamental way in which the Government can aid the diffusion process is to provide information on the relevant mature technologies to the prospective diffusion actors. For manufacturers this could be information on the options available and a monitoring of design performance at independent testing and certification centres. These activities may already be done at existing research institutions; however the links between industry and research would have to be strengthened so that commercial applications and technical research can develop symbiotically. Ease of access to testing centres by entrepreneurs is also necessary for the new designs to be disseminated to a wide audience of potential manufacturers.

78. Information to consumers can take the form of publicizing new technologies and their costs, benefits, and reliability. It can also involve measurement of the natural resource base of the country and site evaluations. The case of the Nepalese micro-hydro programme illustrates how personal information to individuals on the suitability of new technology can be very helpful in generating demand.

79. This type of information to consumers can be channeled through existing technical extension services, or by the formation of specialist teams with expert knowledge on the technology. The former may be included at little cost, but the latter teams are more likely to generate confidence among their clients and should be more fruitful. The degree of personal attention given by these technical specialists depends upon the technology, with the suitability of windmills and water turbines being very sensitive to location.

63/ It should be mentioned that many of the policy measures discussed below, particularly those relating to consumers and distributors, also apply to the encouragement of diffusion via equipment imports.

Table 5: Summary of possible government management activities

Involvement directed to	Technical information dissemination	Resource base measurement	Manpower and training	Taxes, subsidies and credit schemes	Complete marketing responsibilities	Investment of risk capital
Consumers	Technical specifications; Quality certification; Economic feasibility	Site evaluation	Repair and maintenance facilities	Tax incentives; Price subsidy; Bans on alternative technologies; Loans	Purchase equipment directly from manufacturer	
Distributors			Government extension services; Specialist teams	Loans		
Producers	Technical specifications; Testing		Industrial extension services; Vocational training	Tax incentives, Loans		Invest equity

2. Taxes and subsidies

80. The Government should also review its economic policy, and assess the appropriate place for renewable energy technologies in its fiscal and trade regime.64/ The Government may consider a protective tariff for the domestic manufacture of the equipment concerned. The reduction of import tarrifs on materials used to make these technologies may be one suitable option, though there may be some targetting difficulty. The Government may also wish to consider subsidies to consumers to make renewable energy competitive with subsidised petroleum products. These subsidies can be included through tax relief to purchasers and manufacturers where this is applicable, or by a payment to producers for each unit sold.65/ Subsidies can be included as part of social policy to assist poor households. However, they need not be, and can be viewed simply as a method of revising the incentive structure in the energy market for economic ends (i.e., enhanced use of latent renewable energy technology).

81. Another option is to ban alternative technologies, forcing all new consumers to adopt the new technology. This has been done with electric immersion heaters in Israel, Papua New Guinea, and Australia's Northern Territory, where solar water heaters are now used. It is also possible to compel all existing consumers to retrofit their appliances.

3. Credit services

82. The availability of credit to consumers is paramount. If wide-spread diffusion of any equipment is to occur, loans must be available at fair interest rates, with reasonable collateral requirements, and a minimum of processing time. If private sources of capital cannot provide this then the Government must adopt the role of financier. Similarly, credit may be required by manufacturers. To the extent that utilisation of the results of the R & D sector may be enhanced by lowering the risk to be assumed by prospective manufacturers of equipment, soft loans may be extended to the latter as an inducement device. This is done, for example, in Thailand.66/ Preferential rates of interest are also another method of subsidising costs.

4. Support of the distribution system

83. The way in which the Government could be involved with the dissemination of technical information, a requisite for the diffusion of technology itself, has already been noted. The information officials and site evaluation teams can also be involved directly with the sale of installation of new

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64/ In many countries, including developing countries, Governments are increasingly concerned with the impact of the fiscal and trade regime on the innovative behaviour of industrial firms, in general. Whatever review is done should also be seen in this broader context. See UNCTAD (1986).

65/ Vouchers can also be given to potential purchasers.

66/ The Thai Government allocates about $US 400,000 per year in soft loans (usually in amounts ranging $US 10,000 and 40,000 at 10 per cent interest rate and repayable in 3 to 6 years) to equipment makers for production of devices developed through R & D funded by its National Energy Administration.

technologies, essentially acting as an agent for the producing firm.[67] This should help reduce the perceptions of market risks by the manufacturer although uncertainty about the size of the potential market will still remain.

84. The Government may also be able to use existing organizations to distribute equipment. For example, consumers of hot water will already be paying the local electricity utility for their electricity use, and it may be convenient to make the electric company a distributor of solar water heaters. The electric untility could also be responsible for repair and maintenance of the heaters under these circumstances.[68]

85. The Government can give the manufacturer tax subsidies in order to compensate for the remaining market risks, or can eliminate risk entirely by purchasing an agreed number of units of the new equipment (possibly over a period of years) and assuming all reponsibility for its distribution.[69] The choice of manufacturer can be done with competitive bidding to supply the new equipment to specified design tolerances. This is a much higher profile for the Government to adopt, but is perhaps the only way to ensure that the technology is produced.[70] There will still be an incentive for the firm to be efficient at reducing production costs as this will increase profits; but there will be less incentive for the company to try to develop the market and increase sales volumes. This approach may be more appropriate in the initial years of the development of a new market, and is particularly suitable if the Government can use most of the purchases directly (e.g. installing solar water heaters in government-owned housing and office buildings).[71] Naturally the Government must accept that it will have to bear all the market risks.

86. The Government could also become involved in developing the infrastructure necessary for the diffusion process. The ability of purchasers to maintain and repair their own equipment may be very limited, and the Government can help by the establishment of repair facilities, and through technical training programmes for specialized technicians. These educational programmes also have long-term beneficial effects for development, but unfortunately may have a more limited impact in the immediate future. Other long-term investments, such as transportation infrastructure, may also be helpful in creating demand for new technologies in more remote areas. However, such developmental expenditures sometimes lead to migration from rural to urban areas and it is often a real problem for the Government to manage these short-run difficulties, and yet still achieve the intended long-run development goals.

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[67] This would also ensure correct installation procedures are followed. Ward et al. (1984) note that in many African countries the installation of solar water heaters leaves much to be desired.

[68] See Hurst (1986).

[69] Kim (1980) notes that providing a stable demand may be an essential activity for government.

[70] Corruption can be a problem under these circumstances, particularly for long-term contracts.

[71] However, bureaucratic delays may cause problems. An often mentioned complaint is that Government delays payment on procured output (Page, 1979; quoted by Singh, 1977).

5. Government participation in equipment manufacture

87. Instead of contracting to purchase specified quantities of equipment, the Government can help make production more attractive by investing equity in the producing firm. This provides a form of risk-sharing which has many attractions: not only will both private and public equity holders benefit from profits, but the firm is maintained as an entity which can be responsive to the market and can invest profits in market development. The attraction to the Government of a joint venture is that is does not have to take all the risk - some is borne by private capital. This may be important if public funds are limited, although the Government can also establish a completely State-owned company to produce the technology if it has sufficient resources, both capital and manpower.

88. As is obvious from the foregoing discussion, the possible roles for government are many and vary from country to country. The 'necessary' role of government also depends upon the technology and socio-economic conditions. In general, the minimalist approach would focus on the general, infrastructural conditions relating to diffusion such as information dissemination, education and training and improvement of industrial overhead facilities. On the end of more active involvement, government participation as equity holders in equipment manufacture may be suitable under certain circumstances, and may provide sufficient security for private entrepreneurs.72/ Should the State (or external funding agencies) believe that the public sector should not be involved in this kind of manufacturing activity, it is always possible for the Government to sell its equity share once a stable market has developed.

89. However, financial involvement by the Government does not necessarily mean that there will be favourable interactions between the new company and other Government institutions. Stuckey and Juma (1985) in their analysis of ethanol production in Kenya and Zimbabwe observe that although 55 per cent of the equity of the Kenyan ethanol facility was government-owned, co-operation between the plant and the Government was rather weak. Conversely in Zimbabwe, where the Government was not financially involved, there were close relations between the State and the ethanol producer and the decision-making process appears to have involved considerable co-operation. In this latter case the Government seemed still able to exert influence through control of the access to foreign exchange.

90. It has become a cliché that renewable energy technologies are beneficial because they reduce the need for imported oil and generate foreign exchange saving. At a crude oil price of $10 per barrel the importance of this aspect may diminish not only for diffusion through equipment imports but also for diffusion through domestic equipment manufacture if materials and intermediate inputs need to be imported for such activity. However, it should be recognized that the diffusion of mature renewable energy technologies can make an important contribution to the development of rural areas where energy problems are not necessarily affected by a changing international energy situation. Their diffusion can increase the possibilities of expanded energy supply based on local resources and capabilities.

72/ In the Republic of Korea, the Government pioneering the establishment of several industries (e.g. steel, machine tools) and subsequently sold them to the private sector.

91. The use and manufacture of mature renewable energy equipment may have many beneficial developmental effects, not least a stimulant effect on domestic manufacturing industry. The Government can play a major role in information management and delivery. By setting the conditions that will encourage the use of these technologies, it can indirectly increase the role of domestic equipment manufacture in the diffusion process. The Government policy on diffusion of mature renewable energy technologies will have to be based on an analysis of the socio-economic costs and benefits of each technology carried out on a case-by-case basis, taking into account all these aspects. Even after such studies, it may still require the Government to bear risks, and inevitably losses will occur. Nonetheless, controlling uncertainty is a legitimate role of Government and is practised in many different countries for many commodities.

B. Areas for international co-operation

92. Many and diverse programmes of international co-operation already exist for the promotion of application of different mature renewable energy technologies. These have in large part been geared to development, testing and demonstration. Their objectives no doubt lie in widespread diffusion of viable technologies. The present paper has examined the workings of diffusion mechanisms, with a particular focus on the role of domestic equipment manufacture, and argued the need for government policy in this respect. International co-operation through bilateral and multilateral channels can play a useful role by providing complementary support to such national efforts. Developing countries may also find that combining some aspects of their national efforts can strengthen the basis for implementing national diffusion policy. This section discusses some areas in which such international co-operation may be considered.

93. One area in which international co-operation can help concerns the dissemination of relevant information. Although this paper has regarded mature technologies as being well known and standardized, in reality it may be far from clear which particular designs are 'mature' and which are not. Information on standard designs and a selection of possible modifications may therefore be necesssary to set the terms of government policy for diffusion of any technology. International networks have been suggested as one method of disseminating technical information.[73/] The scope of these networks varies, but the development of standards and codes and elaboration of common methods for evaluation are common elements for most. If these networks or other similar arrangements can furnish information on actual performance and costs of technologies installed following a standardized scheme, this will facilitate national policy efforts greatly. Such a scheme may indeed revolve around a small group of "reference countries" which are willing to participate in a given information generation exercise.

[73/] Such networks exist, for example, for wind pumps (i.e., "Global Windpump Evaluation Programme" which developed out of the joint initiative of UNDP World Bank and the Netherlands Government) and biomass gasifiers (i.e., UNDP/World Bank Gasifier Monitoring Programme). Regional networks exist for biogas in Latin America under OLADE, in Africa under the Commonwealth Science Council and in Asia under ESCAP's Regional Energy Development Programme. Similar regional level networking arrangements for small-scale hydro-power are also being promoted by UNIDO in the three regions.

94. A second area for co-operation concerns a joint exercise among developing countries in a region or a subregion to assess the feasibility of equipment manufacture. Regional "unpacking" of projects involving mature renewable energy technologies may be carried out with the aim of identifying the sources and conditions of supply of the equipment, components and related services. This information can be combined with the data on the existing equipment manufacturing activity and technological capability in the countries concerned in order to permit an elaboration of regional manufacturing possibilities. Such an exercise would be of particular relevance for the manufacture of certain key components - for example, blades for windpumps and generators for small-scale hydro power - whose manufacture in individual countries may be constrained whether because of the small size of market or the lack of technological capability. Even in cases where no country in a given region possesses the relevant capability, and technology transfer from outside the region is needed, the task of negotiating the latter would be made easier because of the bigger market involved. The implementation of this scheme will no doubt be easier where there are existing regional industrial co-operation programmes, such as the Andean Pact countries and ASEAN. However, even in regions without such a tradition, a regional unpackaging exercise can indicate areas where complementarity exists; if this is combined with the establishment of standards and codes, trade possibilities may emerge.

95. A third area concerns financing. Provision of appropriate credit arrangements for potential consumers is central to any diffusion policy. The example of the role played by an international finance (i.e., Asia Development Bank) in the micro-hydro equipment diffusion in Nepal demonstrates the value of international co-operation in financing of diffusion. It may be believed that outright donation of equipment will, by reducing the financial burden of the potential users to nothing, promote diffusion. This paper has shown that this is usually not the case for a variety of reasons, including the lack of working capital for complementary inputs, absence of repair and maintenance, lack of spare parts, etc. Where there is local equipment manufacturing capability, such donation is even harmful to the local economic activity. Consideration may, therefore, be given, in bilateral or multilateral aid, to generating or strengthening the domestic diffusion mechanisms in developing countries. One such idea may be to direct co-operation programmes to the building up of the equipment manufacturing capability. Instead of sending the renewable energy equipment itself, equipment to manufacture the renewable energy equipment may be sent. The latter should, of course, be coupled with training of needed manpower as well as designs and production methods. Appropriate arrangements would also have to be made to ensure the supply of raw and intermediate materials at least for the initial period. The domestic R & D institutions may be brought in to such a scheme in order to provide the technical expertise especially for adaptive work. Although it is a roundabout approach to mature energy technology diffusion, such a scheme may in the longer run accelerate the diffusion process.

96. Finally, it will be useful to organize exchanges on the diffusion experience of different developing countries, particularly regarding the policy employed to encourage diffusion. To the extent that the diffusion process is shaped by the particular character of the technology, such exchanges may be organized by different sources of techonologies. Alternatively, different aspects of the diffusion mechanism may be chosen as an object of the exchange. The role which domestic equipment manufacture can play in the diffusion process, or more broadly the build-up and utilisation of domestic technological capability, should receive close attention in this respect.

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